THE OCCURRENCE OF GUTIERREZIA SAROTHRAE ON BOUTELOUA ERIOPODA RANGES IN SOUTHERN NEW MEXICO

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Bouteloua eriopoda Torr. (black grama) is characteristic of the desert plains association described by Weaver and Clements ('29), and extends from southwestern Texas through southern New Mexico, Arizona and northern Mexico. This grass, if not depleted, is the most abundant and valuable forage species on the well-drained sandy or gravelly soils of dry mesas in the region, especially in southern New Mexico.

Jardine and Forsling ('22) have shown that continued overgrazing of *Bouteloua eriopoda* range leads to deterioration of the valuable grasses and the establishment of *Gutierrezia* spp. (snakeweed or broomweed), accompanied by reductions in grazing capacity and loss of soil stability. The ultimate result of continued injudicious grazing may be a transformation of the *Bouteloua* range to the *Prosopis* (mesquite) sand dune scrub association. Periodic drought is partly responsible for the deterioration, because of the wide spacing of plants resulting from low rainfall, and the facility with which the range is overgrazed when inadequate precipitation causes poor forage production.

Many ranchmen believe that *Gutierrezia* will crowd out the valuable forage grasses on the range. This opinion results from failure to recognize overutilization and ignoring the fact that on grass ranges, the unpalatable *Gutierrezia* plants are subject to little foliage removal by cattle, while the palatable grasses, when overutilized, sometimes are eaten to within a half inch of the soil surface.

In order to determine the trend of *Gutierrezia* occurrence in the *Bouteloua eriopoda* association, and to establish its significance in plant succession, a study of the problem was initiated.

The work upon which this paper is based was done near Las Cruces, New Mexico, on the Jornada Experimental Range, a branch of the Southwestern Forest and Range Experiment Station, Forest Service, U. S. Department of Agriculture.

METHODS OF INVESTIGATION

In July, 1924, three one by three meter quadrats were established in a *Bouteloua eriopoda* association supporting a fairly dense stand of *Gutierrezia*

[1] Acknowledgment is due J. D. Schoeller, who established this study in 1924, and collected the data until 1927. Constructive criticism of the report was given by several members of the Forest Service.

sarothrae (Pursh) Britt. & Rusby.[2] The quadrats were located within an area one hundred yards in diameter, according to the following scheme:

Quadrat 1. A stand of young *G. sarothrae* seedlings had become established, but *B. eriopoda* was still dominant.

Quadrat 2. *B. eriopoda* was decidedly dominant, but *G. sarothrae* seedlings were present.

Quadrat 3. *G. sarothrae* appeared to be dominant, with several mature plants and numerous seedlings, but *B. eriopoda* made up 38.9 per cent of the quadrat tuft area.

The vegetation on the quadrats was mapped in the autumn of each year, in 1924 by the strap method, and from 1925 to 1930, inclusive, by the chartograph method, as described by McGinnies ('30). *Bouteloua* tufts and the *Gutierrezia* plants were mapped at one inch above the soil surface, and were compiled in square centimeters. The extreme diameter and height of each *Gutierrezia* specimen were measured and recorded. Supplementary notes on vegetative and biotic conditions were made for the area in which the plots were located, each time the quadrats were mapped. These notes included a careful ocular estimate of the plant density and composition on the area, based upon the grazing reconnaissance method developed by the Forest Service, as described by Campbell ('31).

The degrees of grazing use were recorded in June each year as a part of the regular grazing capacity project. These data show in percentages the volume of range feed used by grazing animals and are based upon the growth requirements of *B. eriopoda.*

Factors Influencing the Vegetation

In order to understand the conditions under which the study was made, it is necessary to present available measures of the habitat, which may be grouped conveniently under climatic, physiographic, and biotic factors.

Climatic Factors

The following data show the monthly mean maximum and minimum air temperatures at the Jornada range headquarters about 6 miles northeast of the study area, from 1914 to 1930, in degrees Fahrenheit:

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Max.	55.3	62.5	67.2	74.0	83.4	94.7	93.0	91.8	86.8	76.7	63.9	53.1
Min.	21.2	26.4	31.1	39.1	46.7	56.2	63.9	61.8	55.1	42.0	28.9	22.2

Temperatures are favorable for growth from April into October, but rainfall limits the growing season during most years to the three months of July, August and September, as shown by the following monthly precipitation

[2] In this report, *G. sarothrae* includes *G. longifolia* Greene, *G. tenuis* Greene, and tentatively *G. juncea* Greene, fide Dr. S. F. Blake, Bureau of Plant Industry, United States Department of Agriculture.

means, expressed in inches, at the Jornada range headquarters from 1914 to 1930, inclusive:

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
0.28	0.32	0.48	0.16	0.64	0.28	1.82	1.73	1.16	1.09	0.42	0.64

Occasionally the growing season may continue into early October, but low temperatures usually limit growth after October 15. During the summer, the mean evaporation from a free water surface is approximately 12 inches or less per month, and wind movement is well under 3000 miles per month, as measured at Elephant Butte Dam (Linney, '17–'30), a station reasonably comparable to the Jornada range. During the spring, however, the peak of unfavorable growth conditions is reached, with low rainfall, mean evaporation well over 12 inches per month during May and June, and with mean wind movement from 3000 to 3500 miles per month during the entire spring period.

Physiographic Factors

The quadrats were located in a *B. eriopoda* association on soil which is a grayish to pale reddish, fine to medium sand, with a comparatively high percentage of gravel, and characterized by a loose, pervious structure. At variable depths from 2 to 6 feet, the surface layer of sand and gravel is underlain by a hard, whitish, calcareous caliche. In general, it is a porous dry soil, with a structure unfavorable for moisture retention.

The site of the study is approximately 4200 feet above sea level on the gently undulating, featureless plain of the Jornada mesa.

Biotic Influences

The biotic community on the range, as Taylor ('30) points out, includes not only the forage plants and livestock, but all the plants and native animals. The flora, domestic livestock, and certain fauna will be considered with the experimental results, but the great majority of native fauna must be given only passing attention, largely because so little is known concerning the various species and their food requirements.

In a partial census of the fauna associated with *Yucca elata,* a member of the *Bouteloua* association, Campbell and Keller ('32) listed 39 insect species, 2 reptiles and 3 mammals. Little is known of the interrelationships of these and many other animals to each other and to the vegetation. Although it is known that such genera as *Lepus, Sylvilagus, Dipodomys,* and *Neotoma* either consume or destroy large quantities of plant material, the available data are insufficient to determine whether the value of such animals in building up soil fertility compensates for their removal of forage. On the study area the rodent population was not excessive at any time between 1924 and 1930, but insects clearly affected the *Gutierrezia* in 1925 and 1927.

The Bouteloua eriopoda Association

The plant density and composition of the *B. eriopoda* association may vary considerably between different sites and different stages of development on the same area. A representative association, after two or three years of favorable rainfall and conservative grazing supports a plant density of approximately 0.35, of which 60 to 70 per cent is *B. eriopoda* (fig. 1). The sand dropseed grasses, *Sporobolus cryptandrus* and *S. flexuosus,* and three awn grasses, *Aristida pansa* and *A. purpurea,* make up about 15 per cent of the stand. *Triodia pulchella* and the annual grasses *B. barbata* and *A. ad-*

Fig. 1. General view of a *Bouteloua eriopoda* association with Quadrat 2 in the foreground, 1931.

scensionis are present, along with the following forbs, listed in order of their abundance: *Croton corymbulosus, Lesquerella fendleri, Solanum elaeagnifolium, Dithyraea wislizeni, Cassia bauhinioides, Psilotrophe tagetinae,* and others. Of the shrubs, *Gutierrezia sarothrae* constitutes from 5 to 10 per cent of the plant cover; with *Yucca elata, Prosopis glandulosa, Ephedra trifurca* and others contributing 4 or 5 per cent. Although all of these species must be considered with the *Bouteloua* association on large areas, only *B. eriopoda* and *G. sarothrae* will be considered in detail, since they were the only species present on the quadrats throughout the period of study, except for occasional forbs or annual grasses.

BOUTELOUA ERIOPODA

This is a perennial, tufted short grass with branching, whitish woolly culms which may vary from 4 to 36 inches in length (fig. 2). Many of the stems are creeping stolons, and produce buds at the nodes, which may take root and grow into new tufts. The plant has a finely divided, well developed root system, mainly in the upppermost 10 inches of soil.

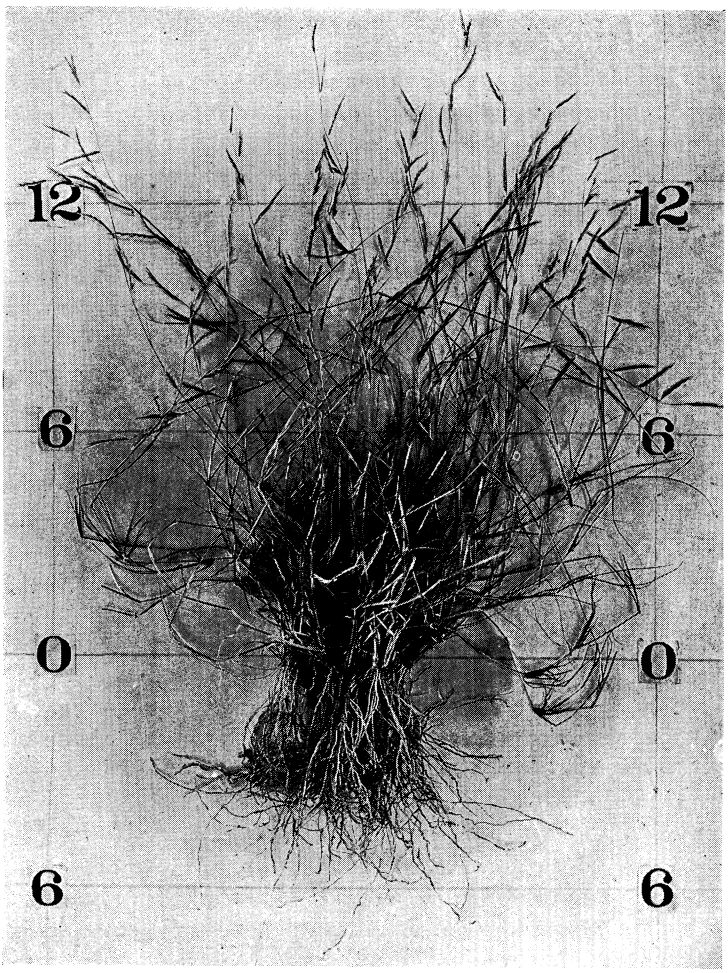

FIG. 2. A tuft of *Bouteloua eriopoda,* showing the character of root system, flower stalks and stolons with rooting buds at the nodes. Dimensions in inches.

The principal spread of the *Bouteloua* comes from lateral extension of individual tufts, as a result of new peripheral stems. Nelson [3] has shown

[3] **Nelson, Enoch W.** 1930. The influence of precipitation and grazing upon black grama range. (MS.)

that increase in tuft area by this method may amount to 190 per cent in favorable growing years. The production of new plants from rooted buds on the stolons also is an important method of vegetative reproduction, mainly during years with above-average summer rainfall.

It reproduces very sparingly from seed in southern New Mexico, largely because of the production of poor seed. A few seedlings have been observed on the gravelly foothills of the Jornada range, but none were charted on the quadrats in this special study. Jackson ('28) found that the 1926 collections of *B. eriopoda* seed on the Jornada range were simply sterile florets, and obtained no germination in any of the samples. Wilson ('31) obtained germination percentages as high as 11.5 per cent from samples collected above 4400 feet elevation but the average germination for all samples of *B. eriopoda* seed collected from 1923 to 1929 was only 3.72 per cent.

Since it reproduces almost entirely by vegetative means, its restoration on depleted areas is necessarily slow, especially where it has been eliminated. Study of the plant has shown that cattle will eat it to within a half inch of the ground if feed is scarce, but that such close use is fatal if continued. At least two inches of stubble and 15 per cent of the flower stalks must be left on the ground each year, if a reasonably good stand of *B. eriopoda* is to be maintained.

Gutierrezia sarothrae

This is a woody perennial of the Asteraceae, from 6 to 36 inches high, with numerous erect stems growing from a woody base. The leaves are linear, and the heads are small and numerous on the paniculate inflorescences at the summits of the stems. Observations have shown that viable seed are matured in sufficient numbers to produce numerous seedlings on the range in favorable years. The seedling establishes a deep taproot during the first season, and develops abundant lateral roots as it matures (fig. 3). Campbell ('29) observed that the development of lateral roots is more conspicuous when the plant is isolated than when it grows near other plants. Branches of the more mature specimens often produce adventitious roots when they are partially covered with drift sand.

In contrast to the high forage value of *B. eriopoda,* the *Gutierrezia* seldom is eaten by cattle on the Jornada range. Dayton ('31) reports that it is reputed to be fair browse for cattle and horses, during the spring and fall in Utah and eastern Nevada, presumably because there is no better feed available. It is regarded by many stockmen as poisonous to livestock if eaten in considerable amounts. Rodents cut off many branches of the plant, and jack rabbits, *Lepus californicus texianus,* often rest in the shade of the larger bushes. As pointed out by Jardine and Forsling ('22), its presence in dense stands on the range may be taken as an indication of over-grazing, but Campbell ('29) has shown that it aids greatly in stabilizing loose windblown soils in the *Prosopis* sand dunes.

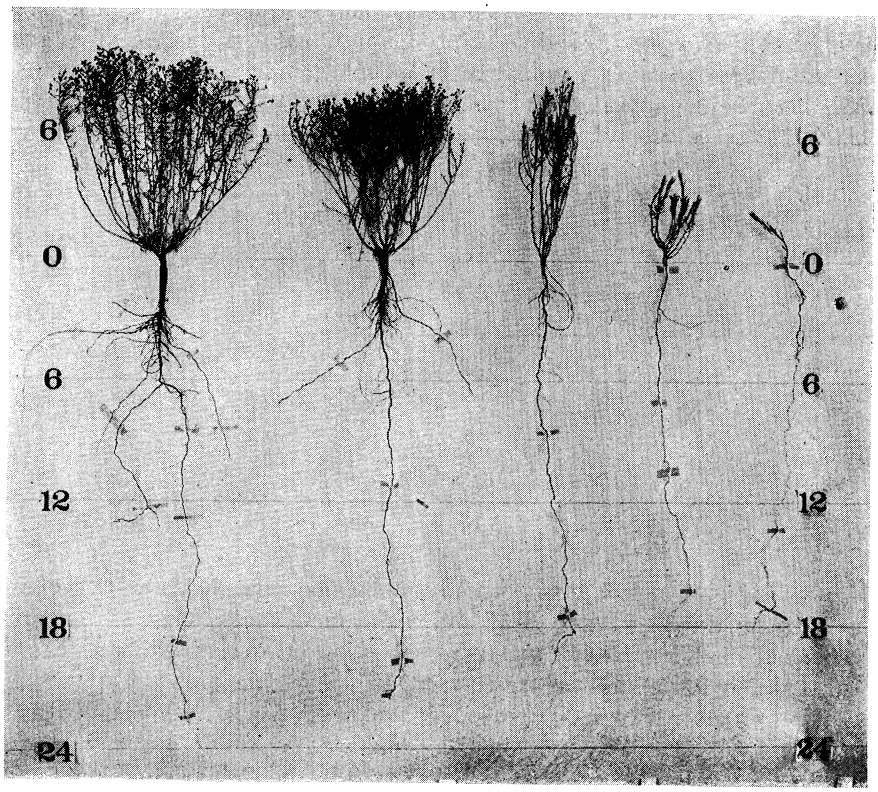

FIG. 3. *Gutierrezia sarothrae,* showing stages of development from seedling to mature plant. Dimensions in inches.

RESULTS OF QUADRAT STUDIES

Prior to the establishment of the quadrats, the area in which they were located had been fully utilized nearly every year from 1915 to 1924. In 1917, 1920 and 1921, the area was overutilized slighty. In addition, six of the ten years were well below average in summer rainfall, three were approximately average, and only one was well above average. Although the area was conservatively utilized in 1924, when the quadrats were established, the summer rainfall was only 1.82 inches, or about one-third of the average summer rainfall for the area.

As a result of these conditions, only 10 per cent of the soil surface was covered with vegetation in 1924. The plant cover was 63 per cent *B. eriopoda,* 20 per cent *G. sarothrae* and 17 per cent other plants. Thus the area was in a depleted condition with enough soil space available for both the grass and the shrub to spread during the more favorable climatic conditions and light utilization which prevailed from 1925 to 1930.

Table I shows the numbers of specimens and tuft areas at one inch above the ground of *B. eriopoda* and *G. sarothrae* on Quadrat 1, in the fall of each year from 1924 to 1930, with summer and total annual rainfall at a station 1.25 miles northwest of the quadrats, and grazing use of the study area from 1923 to 1930.

TABLE I. *Tuft numbers and areas of Bouteloua eriopoda and Gutierrezia sarothrae, precipitation and grazing use on Quadrat 1, 1923 to 1930 inclusive*

Year	Precipitation		Grazing use	Bouteloua		Gutierrezia	
	Annual	Summer seasonal		Tuft area	Tufts	Tuft area	Plants
	Inches	*Inches*	*Per cent*	*Sq. cm.*	*Number*	*Sq. cm.*	*Number*
1923	8.79	3.53	100	—	—	—	—
1924	3.57	1.82	85	836	158	219	13
1925	7.06	4.01	0	851	117	67	5
1926	18.53	8.95	0	677	133	208	7
1927	9.30	8.31	0	1854	115	730	6
1928	9.52	3.68	25	1958	136	522	5
1929	13.80	8.94	15	4092	155	646	21
1930	6.77	4.61	15	4061	157	405	4

In considering table I, it is essential to remember that the summer growing season began usually in early July and ended in October, when the quadrat, three square meters in area, was mapped. The utilization estimates are so calculated that 100 per cent represents proper use for the type.

When Quadrat I was first mapped, the small *Gutierrezia* plants apparently were well established, but the *Bouteloua* was dominant, and both species were rather low in area. During 1924 and 1925, the *Gutierrezia* plants were attacked by beetle larvae, *Crossidius* sp.,[4] which establishes galleries in the woody roots and lower stems of the plants. As a result of this infestation, and the extremely low rainfall in 1924, 8 of the shrubs died in 1925. These conditions had a delayed effect upon the *Bouteloua,* as is shown by its reduced tuft area in 1926. Its subsequent steady gain resulted from the exceptionally high rainfall from 1926 to 1929, with only the summer rainfall of 1928 falling below average. The exclusion of livestock from the area from 1925 to 1928, and the light utilization during the remaining years, also facilitated the spread of the grass tufts.

While the *Bouteloua* was increasing steadily in tuft area, the *Gutierrezia* was attacked by leaf rollers in 1927, so that two shrubs had died by 1928. As a result of the high spring and summer rainfall in 1929, 16 *Gutierrezia* seedlings started that year, but during the dry winter and spring of 1930, all of these seedlings and one older shrub died. In 1930, the 4 surviving shrubs occupied nearly double the quadrat area of the 13 original plants. They were in fairly good condition, with an average height of 28 cm. and an average extreme diameter of 24 cm. It is important to note that none of the 18

[4] Adult beetles collected on flowers of *G. sarothrae* in 1932 were determined as *Crossidius pulchellus* Lec., by Dr. O. Park, Dept. of Zoology, University of Illinois.

seedlings which appeared during the 6 years survived, and only 30.7 per cent of the original *Gutierrezia* plants were left in 1930.

Table I shows that the changes in the *Bouteloua* tuft area, and in *Gutierrezia* numbers and tuft areas, may be correlated fairly readily with climatic and biotic influences. The numbers of *Bouteloua* tufts are more difficult to correlate because they vary as a result of the following possible reactions: (1) reproduction by stolons and rooting sets, (2) the consolidation of several small tufts during years favorable for growth, (3) the disintegration of large tufts as a result of unfavorable growth conditions, and (4) the death of tufts.

The rainfall and utilization data in table I apply also to table II, which shows the tuft numbers and areas for the *Bouteloua* and *Gutierrezia* plants on

TABLE II. *Tuft numbers and areas of Bouteloua eriopoda and Gutierrezia sarothrae on Quadrats 2 and 3*

	Quadrat 2				Quadrat 3			
	Bouteloua		Gutierrezia		Bouteloua		Gutierrezia	
Year	Tuft area	Tufts	Tuft area	Plants	Tuft area	Tufts	Tuft area	Plants
	Sq. cm.	*Number*	*Sq. cm.*	*Number*	*Sq. cm.*	*Number*	*Sq. cm.*	*Number*
1924	706	138	190	8	386	81	608	37
1925	562	106	62	5	473	62	69	7
1926	1066	96	284	7	653	57	320	28
1927	1773	96	524	8	1428	81	628	23
1928	1767	121	427	8	1901	110	536	23
1929	3768	144	596	8	3611	120	908	24
1930	3900	134	591	7	3107	114	751	21

Quadrats 2 and 3 from 1924 to 1930. These quadrats show much the same general trend as Quadrat 1, but since they were established under somewhat different conditions, they require individual analysis.

When Quadrat 2 was established, *B. eriopoda* was decidedly dominant, and only 8 *Gutierrezia* seedlings were present. During the six years of study, the changes in *Bouteloua* tuft area practically paralleled those on Quadrat 1; except that the drop in area as a result of the dry conditions during 1924 came in 1925, instead of in 1926 as on Quadrat 1. In addition, the *Bouteloua* area continued to increase on Quadrat 2 in 1930.

A severe mortality of *Gutierrezia* seedlings occurred on Quadrat 2 in 1925, and new seedlings appeared the two following years, just as on Quadrat 1. Of four seedlings which appeared on Quadrat 2 during the six years, only one survived, while 5 of the original 8 *G. sarothrae* plants lived through the period; and one plant, outside the quadrat at first, grew so large that it was charted on the area after 1926. In 1930, all 7 plants were in fairly good condition, with an average height of 21.5 cm., and an average extreme diameter of 30.3 cm.

Table II shows also the data for Quadrat 3, which in 1924, supported only 386 sq. cm. of *Bouteloua* and clearly was dominated by the *Gutierrezia*, mostly large mature plants, with a total quadrat area of 608 sq. cm. On this

plot the *Bouteloua* tuft area increased steadily to a maximum of 3611 sq. cm. in 1929, but suffered a small loss in 1930.

The most serious *Gutierrezia* mortality of all three plots occurred on Quadrat 3 in 1925 when 30 plants died, but 19 seedlings started in 1926, and two other plants, originally outside the plot, grew enough to be mapped on the quadrat. During the remainder of the study, 12 plants died, but 5 seedlings came up. Of the 24 seedlings which started on the quadrat in six years, 16 survived; and of the plants on the quadrat when it was established, all of the mature specimens died, and only three of the younger plants survived, while two outside plants grew onto the quadrat. In 1930, the average height of the surviving plants was 21.0 cm., with an average extreme diameter of 20.0 cm.

A recapitulation of the quadrat data shows that both *B. eriopoda* and *G. sarothrae* may be found in a depleted condition as a result of continuous drought, that both may recover during years with above average rainfall, especially the *Bouteloua* when it is utilized lightly. It appears that the large mature plants of *G. sarothrae* are quite susceptible to insect injury, as was shown by Quadrat 3 in 1925; that the well established seedlings from 2 to 4 years old are more resistant to both insect and drought conditions; and that one year seedlings are very susceptible to death during periods of low rainfall, as shown by the high mortality on Quadrat 1 in 1930. It appears further that if *B. eriopoda* is too seriously depleted, as on Quadrat 3 in 1924, the *Gutierrezia* becomes so well established that it covers more area for many years after the depletion than it does on areas where the *Bouteloua* was not so badly depleted, as on Quadrats 1 and 2. It is interesting to note that the maximum combined quadrat area of the *Bouteloua* and the *Gutierrezia* was very close on all three quadrats, 4738 sq. cm. on Quadrat 1 in 1929; 4491 on Quadrat 2 in 1930; and 4519 on Quadrat 3 in 1929.

No conclusive evidence was obtained as to the results of direct competition between the two plants, but in 1927, examination of 50 tufts of the grass growing very near or just under the crowns of mature *Gutierrezia* plants showed a repressing effect on the *Bouteloua.* In many instances the leaves and shorter flower stalks of the grass were wilted or dead; and many tufts showed a retardation of from one to two weeks in the flowering period. In spite of these retarding effects, very few dead *B. eriopoda* plants were found, and on most tufts at least one or two flower stalks grew clear of the *Gutierrezia* plant and developed a spike. Some of the stalks grew vertically and flowered above the bush, but most of them grew horizontally on the soil until clear of the *Gutierrezia,* then turned upward and flowered.

Vegetative Changes on the Experimental Area as a Whole

Table III shows the estimated proportion of soil surface covered by *B. eriopoda, G. sarothrae,* and other classes of vegetation, and the total vegetative cover of the association in which the quadrats were located, for each year

from 1924 to 1930. These data show that in 1924, only 10 per cent of the soil surface was covered with vegetation, estimated on a vertical projection downward of all plant cover. In general these ocular estimates correlate very well with the quadrat data; except for 1925, when an increase in the *Gutierrezia* was recorded, while the quadrats showed a marked reduction. By 1930, substantial increases in area for both the *Bouteloua* and the *Gutierrezia* were shown in both records.

TABLE III. *Estimated proportions of soil surface covered by vegetation on the experimental area, 1924 to 1930 inclusive*

Year	*Bouteloua eriopoda*	Other perennial grasses	Forbs and annual grasses	*Gutierrezia sarothrae*	Other shrubs	Total vegetation
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1924	6.30	0.65	0.80	2.00	0.25	10
1925	8.00	4.00	4.80	2.80	0.40	20
1926	12.90	3.30	10.50	2.70	0.60	30
1927	24.00	3.60	8.00	3.20	1.20	40
1928	24.15	3.15	3.50	3.15	1.05	35
1929	24.45	3.15	1.40	4.90	1.10	35
1930	26.60	1.75	1.45	4.20	1.00	35

The behavior of perennial grasses other than *B. eriopoda,* principally *Sporobolus flexuosus, Aristida pansa* and *A. purpurea,* is significant, as it places them in an earlier stage of succession than the *Bouteloua,* a fact previously inferred in a study of plant succession in *Prosopis* sand dunes (Campbell, '29). These three large, coarse-rooted grasses, all of which reseed rather readily, spread from 0.65 to 4.00 per cent ground cover during 1925, the first year following the severe summer drought of 1924; while the *Bouteloua* increased only slightly, and the *Gutierrezia* suffered from the infestation of *Crossidius* larvae. As the *Bouteloua* and *Gutierrezia* gradually spread after 1925, the three pioneer grasses were reduced in cover percentage. The highly ephemeral value of forbs and annual grasses, also pioneers, is shown by the decided variation in percentage of cover they furnished.

It is evident from table III that the grazing capacity of the study area increased steadily throughout the period of the experiment, along with the consistent spread of *B. eriopoda* each year. The outstanding feature is that the *B. eriopoda* covered approximately 4 times more surface from 1927 to 1930 than in 1924, in spite of the comparatively large proportion of *G. sarothrae* present. It is probable that the grazing capacity of the area would have been even greater, had the *Gutierrezia* been replaced by *B. eriopoda;* but even as the association existed in 1930, it was one of the highest grazing capacity ranges in southern New Mexico.

MANAGEMENT OF BOUTELOUA ERIOPODA RANGES

Even after serious depletion of the *Bouteloua eriopoda* by drought and overutilization, the natural trend is for the restoration of this valuable forage

species during favorable growth years if it is conservatively grazed. The disastrous results of interfering too greatly with this trend may be observed on almost any uncontrolled range in the southwest, where palatable plants have been so seriously depleted by overutilization year after year, that the unpalatable plants such as *Gutierrezia sarothrae* and similar species are now dominant.

The features of range management which are essential to facilitate the natural upward trend of forage production on the *Bouteloua* ranges have been shown by other studies on the Jornada range (Campbell, '31). They include (1) accurate determination of the grazing capacity of each range unit, with the extent of variation due to drought, (2) the actual stocking of the range on a conservative basis during the fall-winter and spring seasons, to allow the fullest vegetative reproduction and forage development of *Bouteloua eriopoda* during the summer grazing season, and (3) an accurate check on vegetative conditions by means of quantitative measurements.

Summary and Conclusions

Bouteloua eriopoda, the most important forage grass in southern New Mexico, and of considerable value as range forage throughout the semi-arid southwest, is subject to serious depletion as a result of drought or overgrazing or both. Its revegetation ordinarily is quite slow because it reproduces poorly by seed, and migrates almost entirely by vegetative processes.

Gutierrezia sarothrae has been observed to replace the *Bouteloua* on areas continually overgrazed. This dominance of the worthless shrubs is due largely to the fact that usually they are not relished by range livestock under ordinary conditions, while the palatable forage grasses may be killed entirely by injudicious grazing, especially during drought. Nevertheless, these shrubs have a definite soil protective value. A study of the occurrence of *G. sarothrae* in a representative *B. eriopoda* association on gravelly sand was started in 1924. The area had been badly depleted by severe drought and some overgrazing. Three quadrats, each containing three square meters were established and charted every year from 1924 to 1930 inclusive.

On the first quadrat, several well established young *G. sarothrae* plants were present in 1924, but *B. eriopoda* was dominant. In spite of attacks by insects in 1925 and 1927 nearly 31 per cent of these plants were alive in 1930, but no new seedlings survived, although many appeared. As a final result of generally above average rainfall and light grazing, the *Bouteloua* area was nearly 5 times greater and the *Gutierrezia* area nearly two times greater in 1930 than in 1924.

On the second quadrat, the *Bouteloua* was decidedly dominant in 1924, and only a few seedlings of *Gutierrezia* were present. 62.5 per cent of the young shrubs survived, while only one new seedling of four became established. By 1930, the *Bouteloua* tuft area was nearly 6.5 times greater, and the *Gutierrezia* area over 3 times greater than in 1924.

The last quadrat supported some *B. eriopoda,* but large mature *Gutierrezia* plants were dominant in 1924. The drought and beetle larvae damage caused so great a mortality among these mature plants that none survived and only three young plants existing in 1924 lived through to 1930. However, on this quadrat, nearly 70 per cent of the seedlings survived, largely as a result of fortunate rainfall distribution during their early growth in 1926 and 1927.

The quadrat data and ocular estimates of composition for the association in which the quadrats were located, show that both *Bouteloua eriopoda* and *Gutierrezia sarothrae* may be depleted as a result of severe drought, such as occurred in 1924. Both species may recover during years with above average rainfall, especially the *Bouteloua* if it is grazed conservatively after it has matured. Although the *Gutierrezia* has a high mortality rate, individual specimens grow to a size sufficient to be prominent even in the climax *B. eriopoda* association.

Observations made on the experimental area show that from 1927 to 1930, its grazing capacity was approximately 4 times greater than in 1924, in spite of the relatively large proportion of ground covered by the *Gutierrezia* during the entire period of study.

All species in the association may be injured by drought, but the trend is toward a decided increase in grazing capacity during years with higher rainfall. Careful range management that encourages this trend will assure sustained range forage production. Injudicious grazing may so deplete the palatable grasses that the shrubs dominate, the soil loses its stability, and grazing values become so low as to require decades for their restoration.

Literature Cited

Campbell, R. S. 1929. Vegetative succession in the prosopis sand dunes of southern New Mexico. *Ecology* **10**: 392–398.

——. 1931. Plant succession and grazing capacity on clay soils in southern New Mexico. *Jour. Agri. Res.* **43**: 1027–1051.

Campbell, R. S., and J. G. Keller. 1932. Growth and reproduction of *Yucca elata. Ecology* **13**: 364–374.

Dayton, W. A. 1931. Important western browse plants. *U. S. Dept. Agri. Misc. Pub. 101.* 213 pp.

Jackson, C. V. 1928. Seed germination in certain New Mexico range grasses. *Bot. Gaz.* **86**: 270–294.

Jardine, J. T., and C. L. Forsling. 1922. Range and cattle management during drought. *U. S. Dept. Agri. Bull. 1031.* 83 pp.

Linney, C. E. 1917–1930. Annual summaries. *U. S. Dept. Agri., Weather Bureau, Climatological Data, N. Mex. Sect.* v. 21–34.

McGinnies, W. G. 1930. The quadrat. *Jour. Forestry* **28**: 23–27.

Taylor, W. P. 1930. Methods of determining rodent pressure on the range. *Ecology* **11**: 523–542.

Weaver, J. E., and F. E. Clements. 1929. Plant Ecology. *New York: McGraw-Hill Book Co.* 520 pp.

Wilson, C. P. 1931. The artificial reseeding of New Mexico ranges. *N. Mex. Agri. Expt. Sta. Bull. 189.* 37 pp.